Cadmium-Zinc-Telluride Sandwich Detectors for Gamma Radiation

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Detectors to sense nuclear and radioactive weapons concealed in transit through borders, airports, and seaports are crucial for the international struggle against terrorism and proliferation of weapons of mass destruction. Currently, germanium detectors offer the best performance in detecting gamma rays; however, they must be operated at cryogenic temperatures. A room-temperature detector is greatly preferred because of cost and ease of use, but the only available alternative is based on cadmium-zinc-telluride (CZT) technology, which offers inferior performance. Here we propose a pathway for CZT gamma detectors to achieve the desired energy resolution of less than 1%. We will use a multilayered structure as shown schematically in Fig. 1, to allow signal collection while simultaneously rejecting noise, which arises primarily due to leakage current.

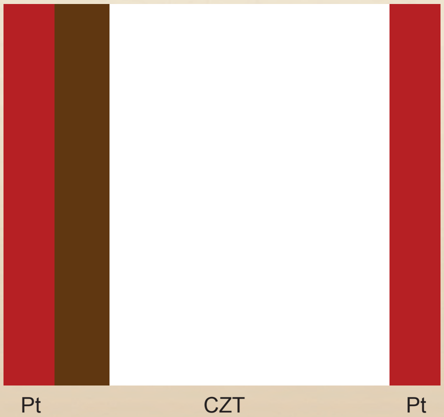

Figure 1. Schematic diagram of a-Si:H/CZT detector layer structure.

Project Goals

With this project, we expect to demonstrate a pathway toward a gamma detector with better than 1% energy resolution that will operate at room temperature. To achieve this goal, we will design a novel structure using bandgap engineering concepts that will result in a 90% reduction in leakage current relative to a resistive device. We also will provide leadership to the detector community by providing a technical roadmap for how to demonstrate a 0.5% energy resolution within five years.

Relevance to LLNL Mission

The solution to the radiation-detector materials problem is expected to have significant impact on efforts to develop detectors that are compact, efficient, inexpensive, and operate at ambient temperature for the detection of special nuclear materials as well as radiological dispersal devices. The multidisciplinary nature of this work and the relevance to national and homeland security align well with LLNL capabilities and missions.

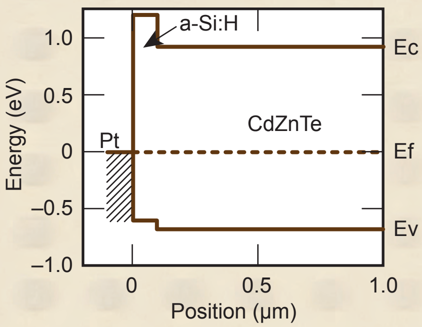

Figure 2. Simulated energy band diagram of a-Si:H/CZT layered structure.

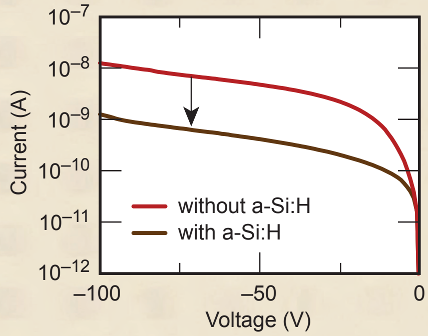

Figure 3. Comparison of current vs. voltage characteristics with (brown) and without (red) a-Si:H contacts.

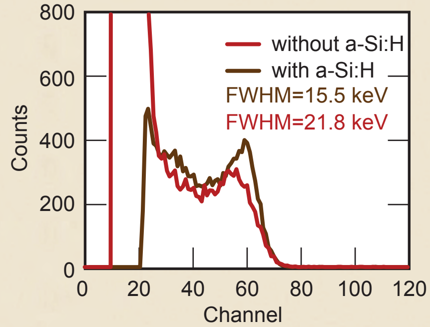

Figure 4. ^{241}**Am gamma spectra for CZT detectors with and without a-Si:H blocking contact.**

FY2009 Accomplishments and Results

In FY2009, we have:

1. benchmarked our models with experimentally gathered data from FY2008 and refined our models to account for discrepancy;
2. designed and fabricated structures with amorphous layers on CZT and carried out both electrical and radiation characterization, which show reduced dark current and improved breakdown voltage over structures without amorphous layers (Fig. 2);
3. demonstrated an effective resistivity of greater than 10^{11} ohm-cm (> 200 V) in material that is considered too conductive for typical CZT gamma detectors with resistivity of 10^9 ohm-cm; and
4. used these structures to characterize the interface and energy barrier between the amorphous material and single-crystalline CZT.

Related References

1. Conway, A. M., B. W. Sturm, L. F. Voss, P. R. Beck, R. T. Graff, R. J. Nikolic, A. J. Nelson and S. A. Payne, "Amorphous Semiconductor Blocking Contacts on CdZnTe Gamma Detectors," *International Semiconductor Device Research Symposium*, December 2009.

2. Voss, L. F., A. M. Conway, B. W. Sturm, R. T. Graff, R. J. Nikolic, A. J. Nelson, and S. A. Payne, "Amorphous Semiconductor Blocking Contacts on CdTe Gamma Detectors" *IEEE Nuclear Science Symposium*, October 2009.

3. Nelson, A. J., A. M. Conway, C. E. Reinhardt, J. J. Ferreira, R. J. Nikolic, and S. A. Payne, "X-Ray Photoemission Analysis of CdZnTe Surfaces for Improved Radiation Detectors," *Materials Lett.* **63**, 180, 2009.

FY2010 Proposed Work

In FY2010, we propose to 1) use x-ray photoelectron spectroscopy to characterize surface Fermi level pinning and add interface physics to our heterojunction detector model; 2) compare current vs. voltage vs. temperature measurements with capacitance vs. voltage measurements for characterization of Schottky barrier height and energy band offsets in amorphous CZT heterojunctions; 3) fabricate amorphous layer CZT heterojunction detectors that have an effective resistivity of greater than 10^{12} ohm-cm in material that is too conductive for typical CZT gamma detectors with resistivity of 10^9 ohm-cm (Fig. 3); and 4) demonstrate a proof-of-principle detector with improved energy resolution (Fig. 4).